

The SNO+ Experiment at SNOLab



Alex Wright

Queen's University
CAP Congress 2008

SNO+

6000 mwe
overburden

850 tonnes LAB
Scintillator

12 m Diameter
Acrylic Vessel

1700 tonnes Inner
Shield H₂O

Support Structure
for 9500 PMTs,
60% coverage

5300 tonnes Outer
Shield H₂O

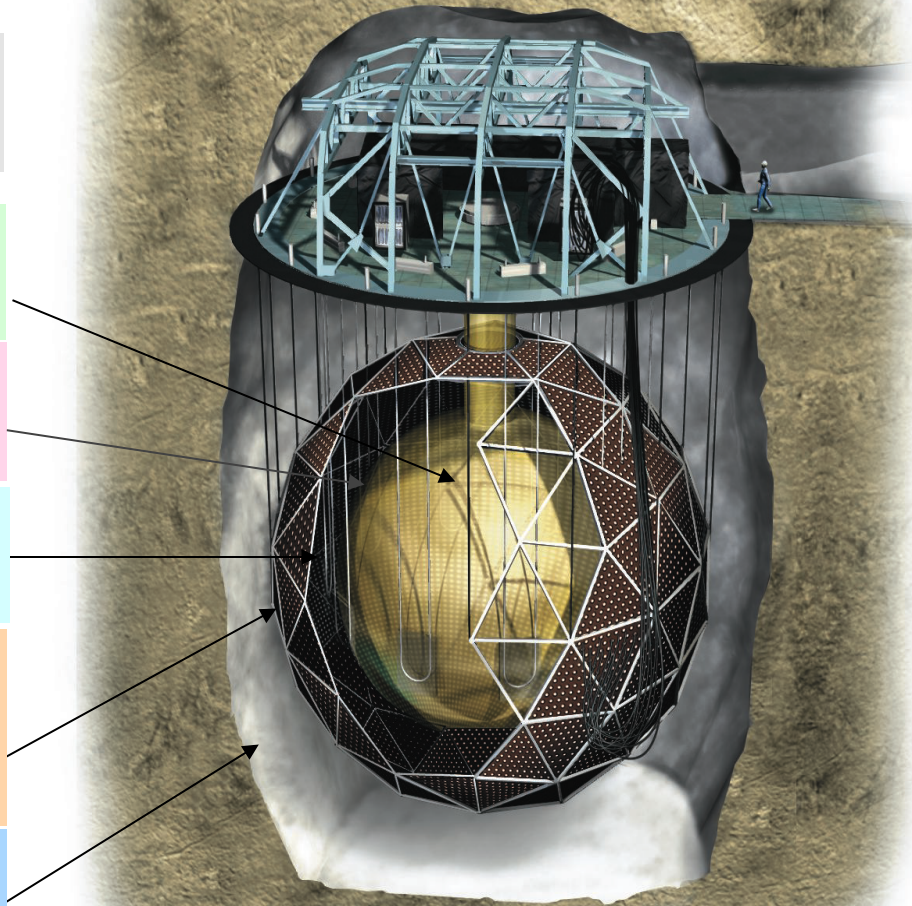


Image courtesy National Geographic

Changes between SNO and SNO+:

- Rope holddown for acrylic vessel
- Scintillator purification plant
- Improve calibration access

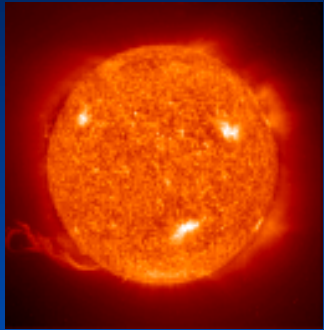
Neutrino interactions:

$$\nu_x + e^- \rightarrow \nu_x + e^-$$

$$\bar{\nu}_e + p \rightarrow e^+ + n$$

Deepest large scintillator experiment in the world!

SNO+ Physics



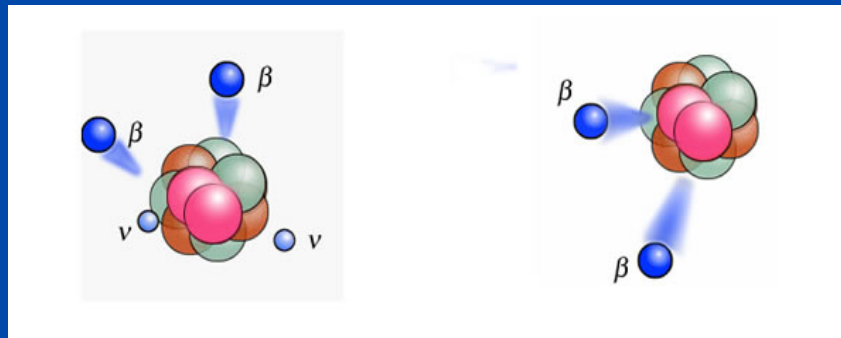
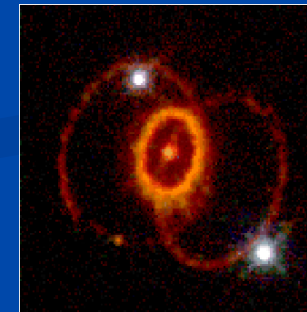
Low Energy Solar Neutrinos

Reactor Antineutrinos

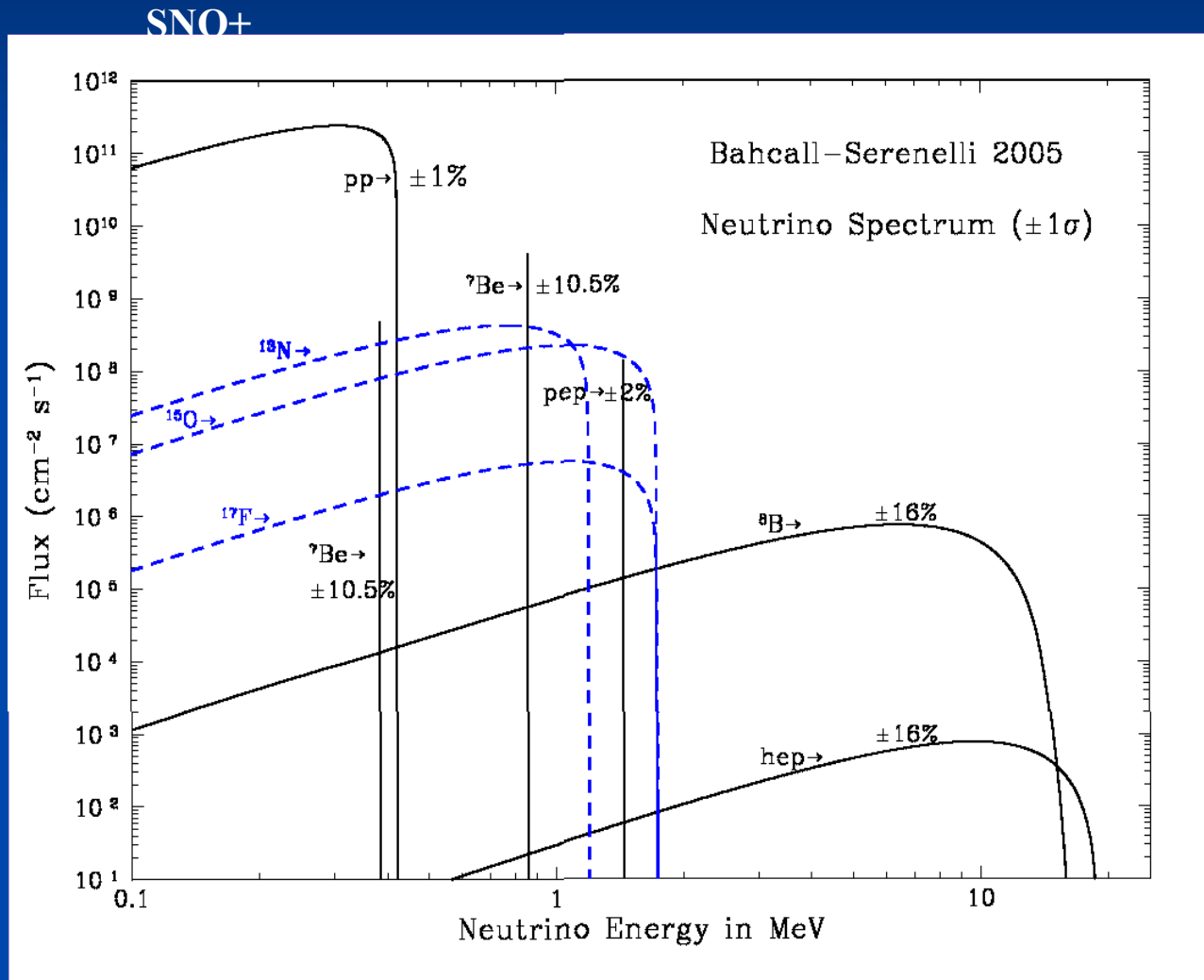
Geo-Neutrinos

Supernova Neutrinos

Neutrinoless Double Beta Decay Search



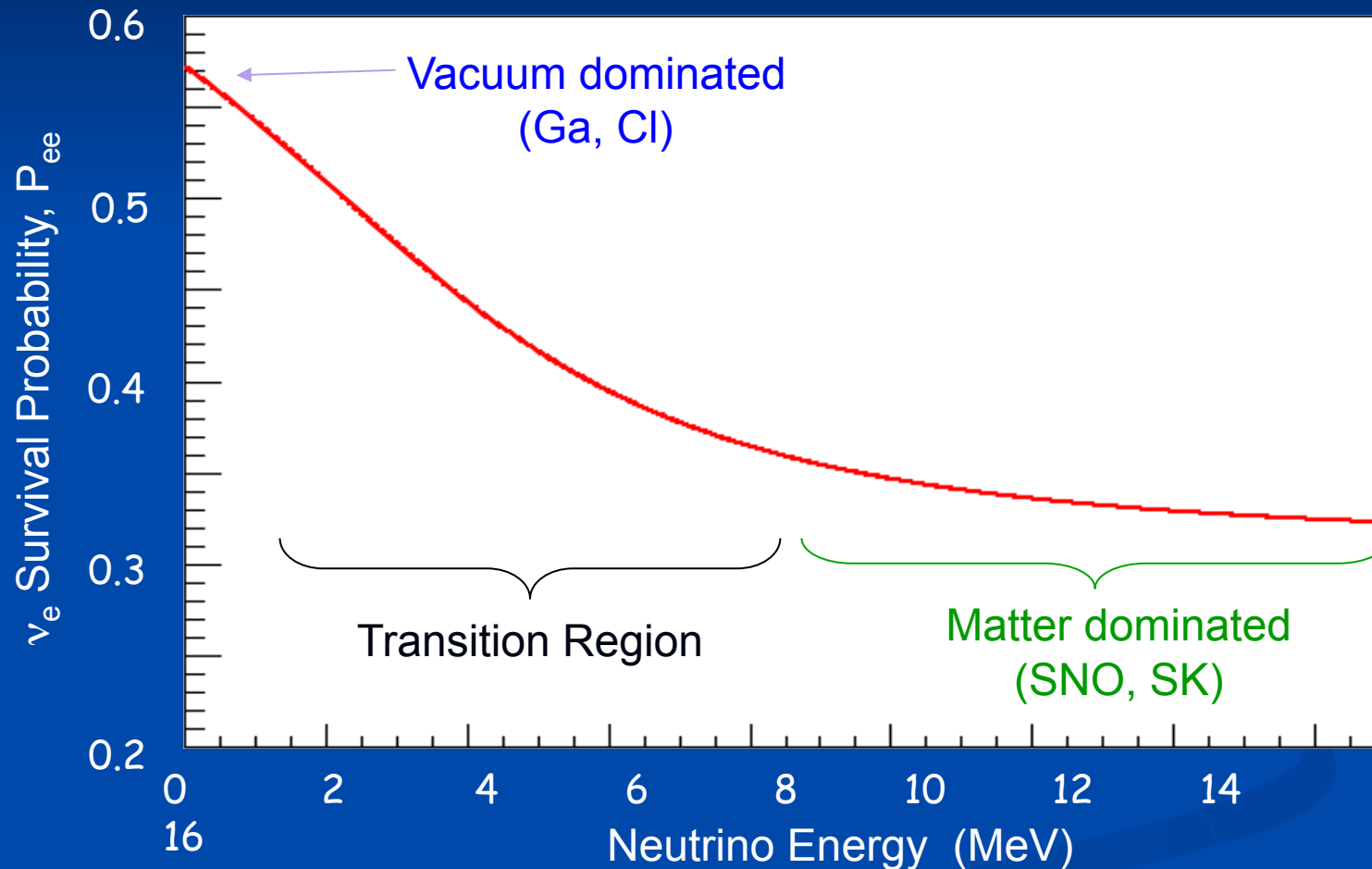
Low Energy Solar Neutrinos



SNO+ will study *pep*, CNO neutrinos.

Neutrino Oscillations

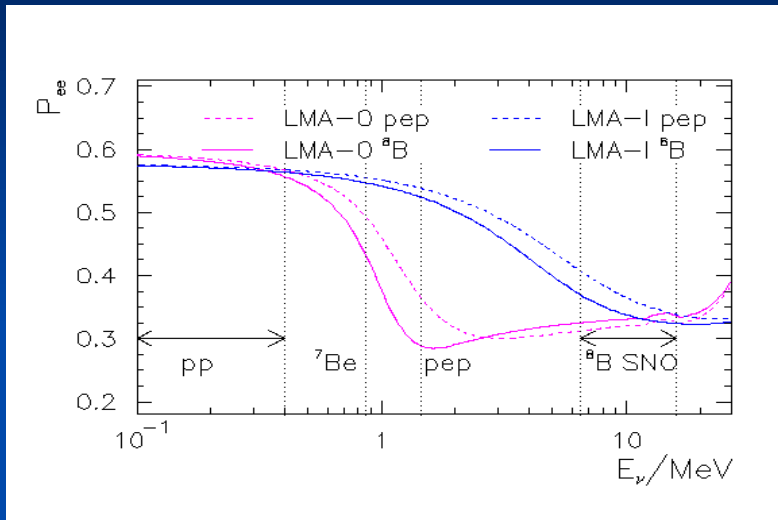
Solar electron neutrino survival probability changes with energy



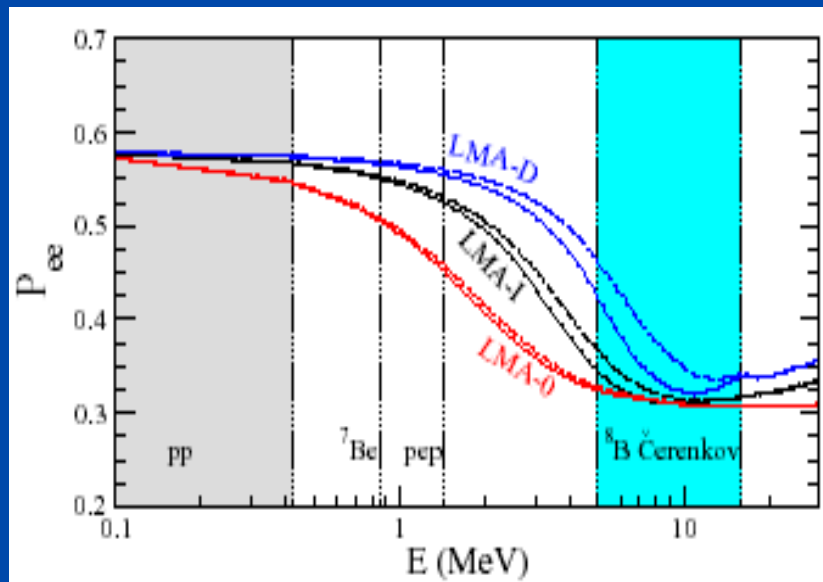
The vacuum and matter survival probabilities are well understood; it is transition region that is sensitive to details of the neutrino-matter interactions

Possible Transition Region New Physics

Non-Standard Interactions

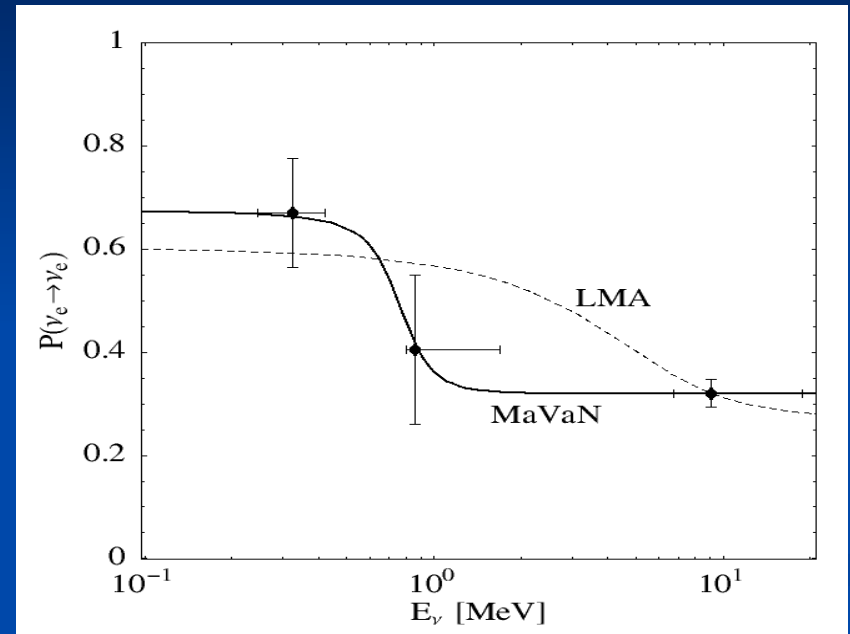


from Peña-Garay , hep-ph/0402266



from Miranda *et.al.*

Mass Varying Neutrinos



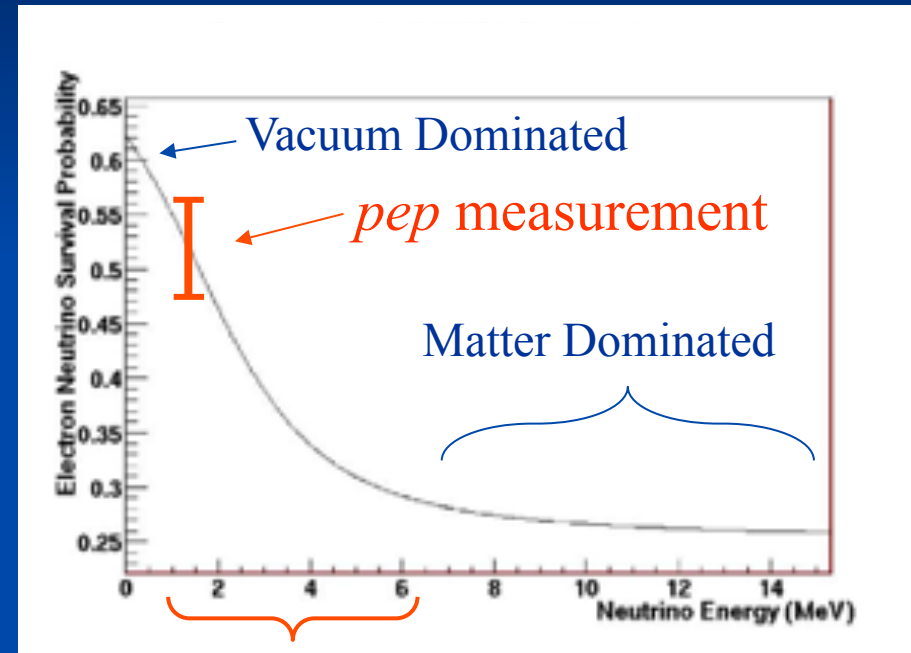
from Barger, hep-ph/0502196

Other Possibilities:

- CPT violations
- Large Θ_{13}
- Sterile neutrino admixture

pep Neutrinos: Probing Neutrino Oscillations

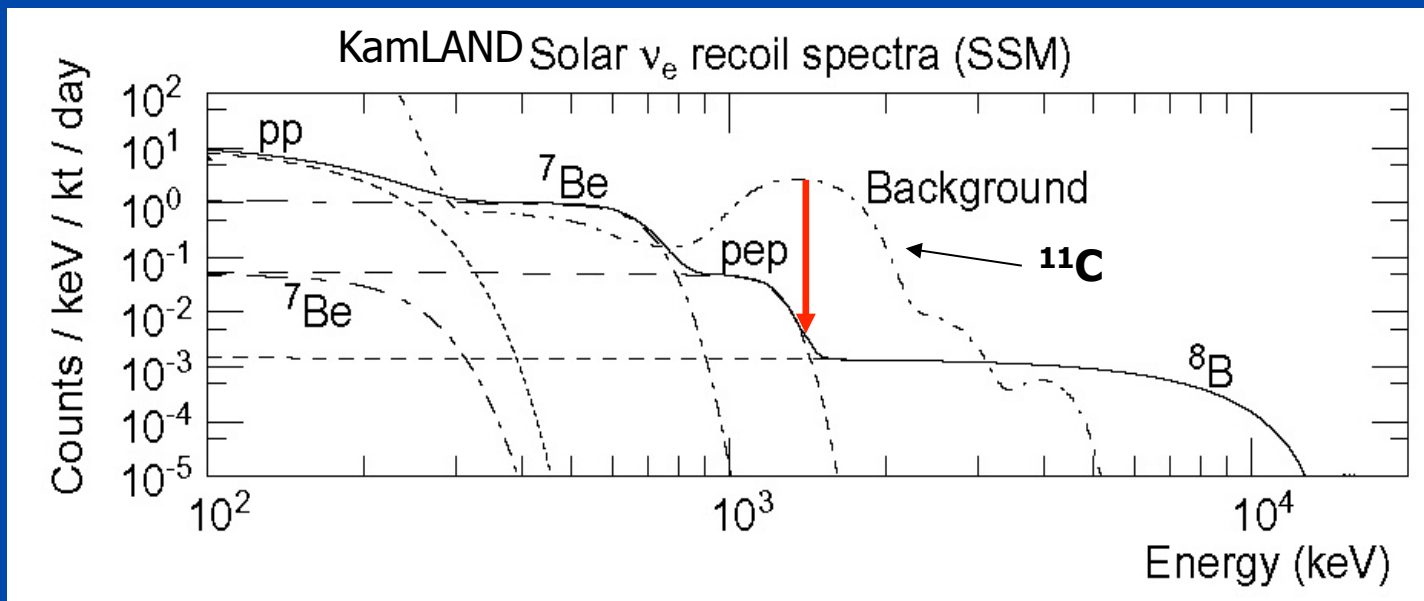
- *pep* neutrinos fall right in the transition region
- Have a small uncertainty on their predicted flux and a high enough rate to allow a precise measurement
- SNO+ can observe the rise in survival probability at low energy
 - Confirm MSW and that we know what's going on
 - Improve precision on θ_{12} and solar only Δm_{12}^2
 - Look for new physics



***Transition Region
sensitive to the details
of the neutrino-matter
interactions***

SNO+ *pep* Measurement Unique

- In other experiments, the *pep* signal is hidden by muon-produced ^{11}C decays
- SNOLAB is deep enough that ^{11}C will not interfere with the *pep* measurement in SNO+

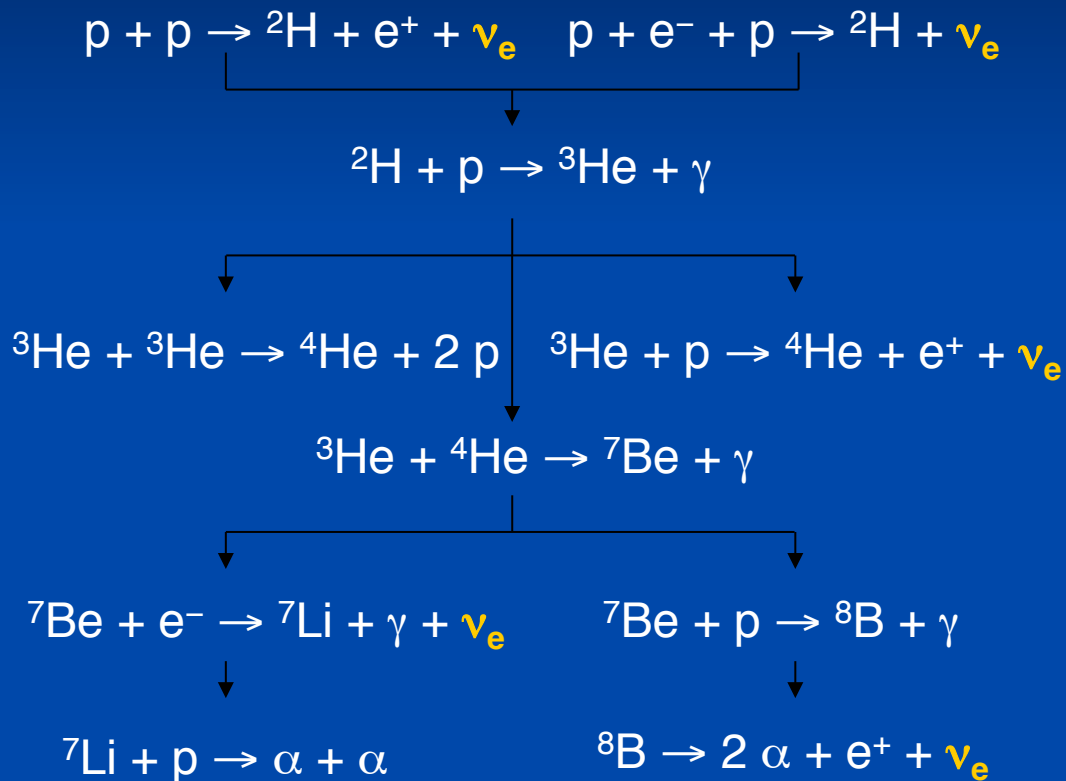


**muon rate in
KamLAND: 26,000 d⁻¹
compared with
SNO+: 70 d⁻¹**

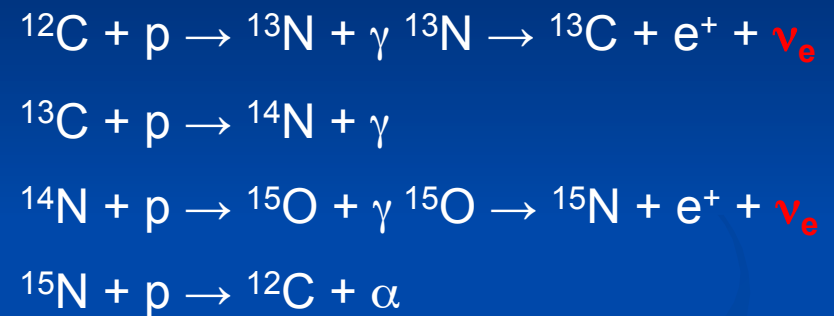
Image from the KamLAND proposal.

CNO Neutrinos

p-p Solar Fusion Chain



CNO Solar Fusion Cycle



***CNO thought to provide
~2% of solar energy,
but this has never been
measured***

***SNO+ can measure the CNO
contribution to solar energy
generation!***

Geo-Neutrinos

- Antineutrinos from β^- decay of K, U and Th in the earth's mantle and crust
- Models suggest that these decays are responsible for 40-100% of the earth's heat

Not well known!

- Use geoneutrinos to measure the earth's radiogenic heat and chemical composition

Geophysics with neutrinos!

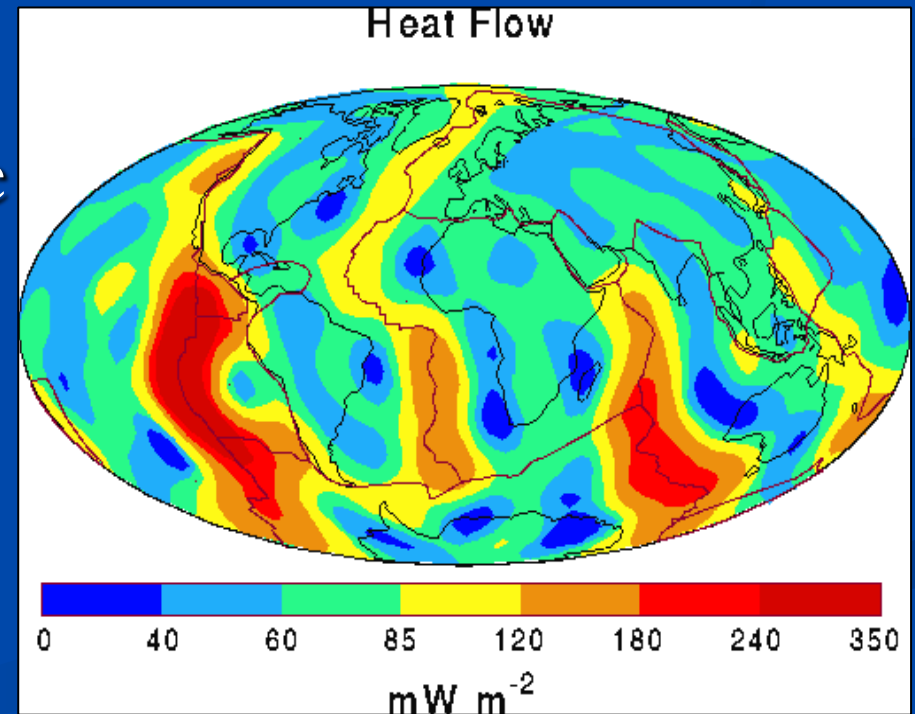
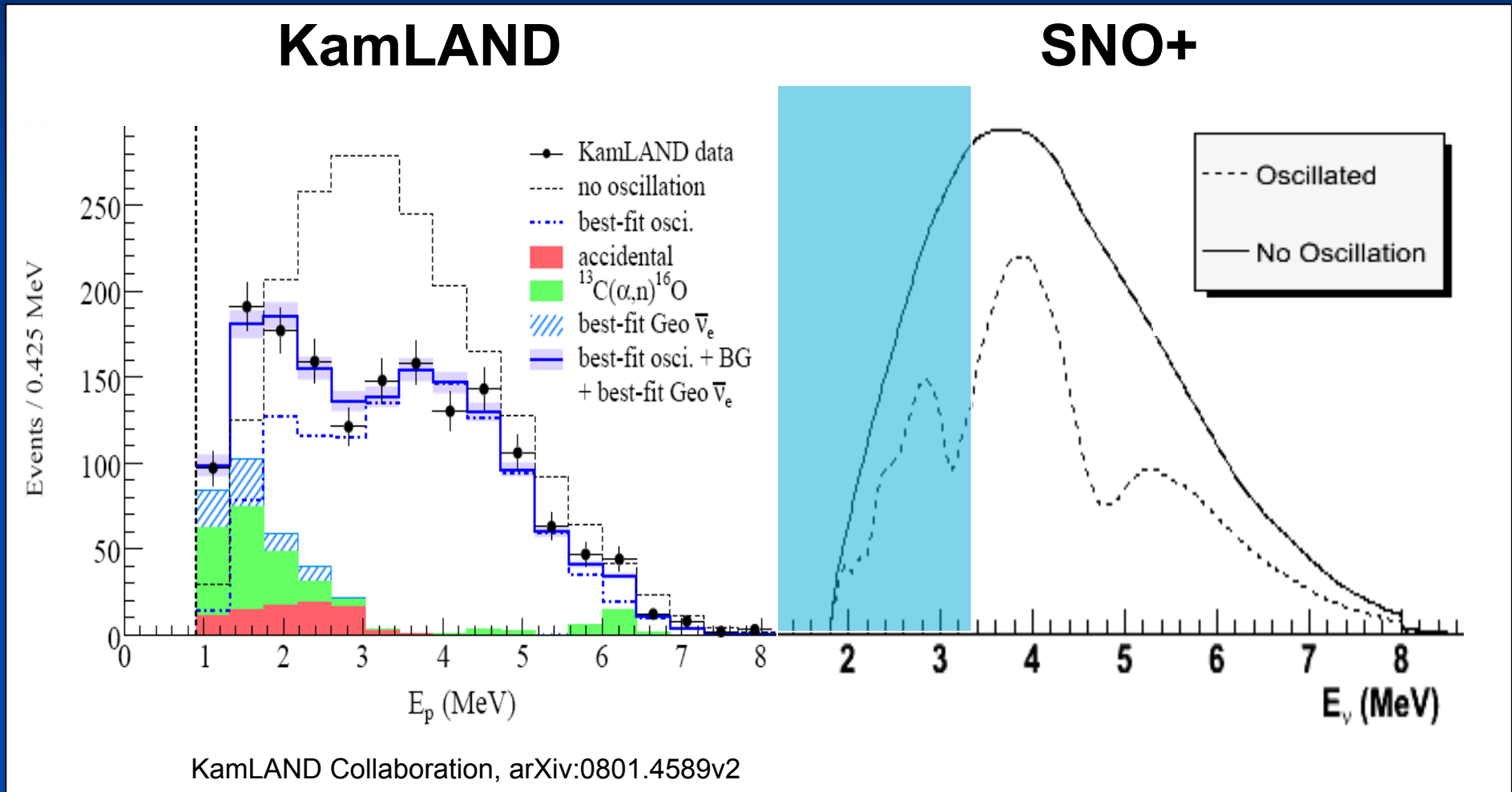


Image from H.N. Pollack, S.J. Hurter and J.R. Johnson, *Review of Geophysics* 31(3), 267-280, 1993

Reactor Antineutrinos

Allow precise study of neutrino vacuum oscillations.



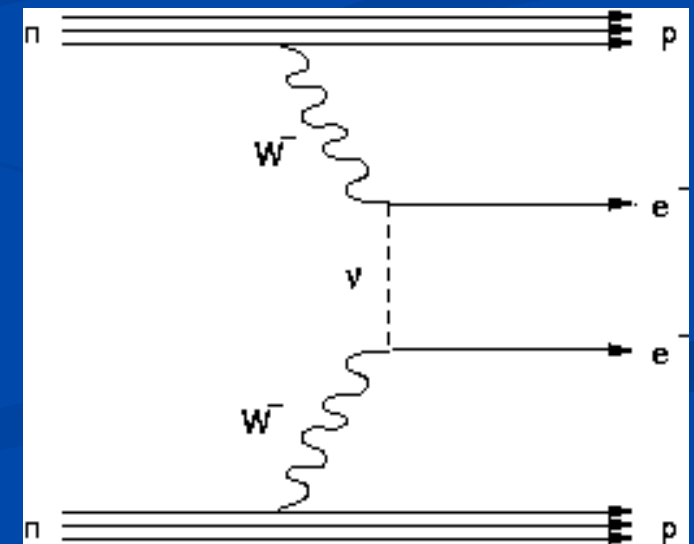
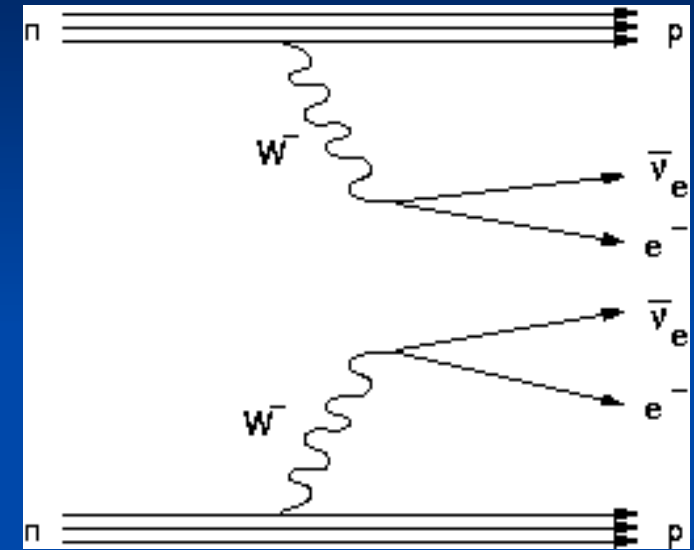
SNO+ can confirm the KamLAND result and further constrain the neutrino mixing parameters.

Supernova Neutrinos

- Type II supernovae release $\sim 99\%$ of their gravitational binding energy as neutrinos
 - Burst detectable at galactic distances
- Neutrinos detection interesting to many areas of physics
 - SN1987a in the Large Magellanic Cloud
 - 24 events detected in 13s (Kamiokande, IMB, Baksan)
 - Papers on neutrino oscillations, neutrino mass, axion mass, the size of compact dimensions in the universe
- Neutrinos provide ‘supernova early warning’

Neutrinoless Double Beta Decay

- Open question: are neutrinos Majorana or Dirac particles?
 - Are they their own anti-particles?
- In double beta decay, a nucleus releases two electrons and two antineutrinos:



$$(A, Z) \rightarrow (A, Z + 2) + 2e^- + 2\bar{\nu}_e$$

- If neutrinos are Majorana, sometimes neutrinoless double beta decay occurs:

$$(A, Z) \rightarrow (A, Z + 2) + 2e^-$$

Images from the NEMO collaboration.

Searching for neutrinoless double search involves looking for a tiny monoenergetic peak at the end of a large double beta decay continuum.

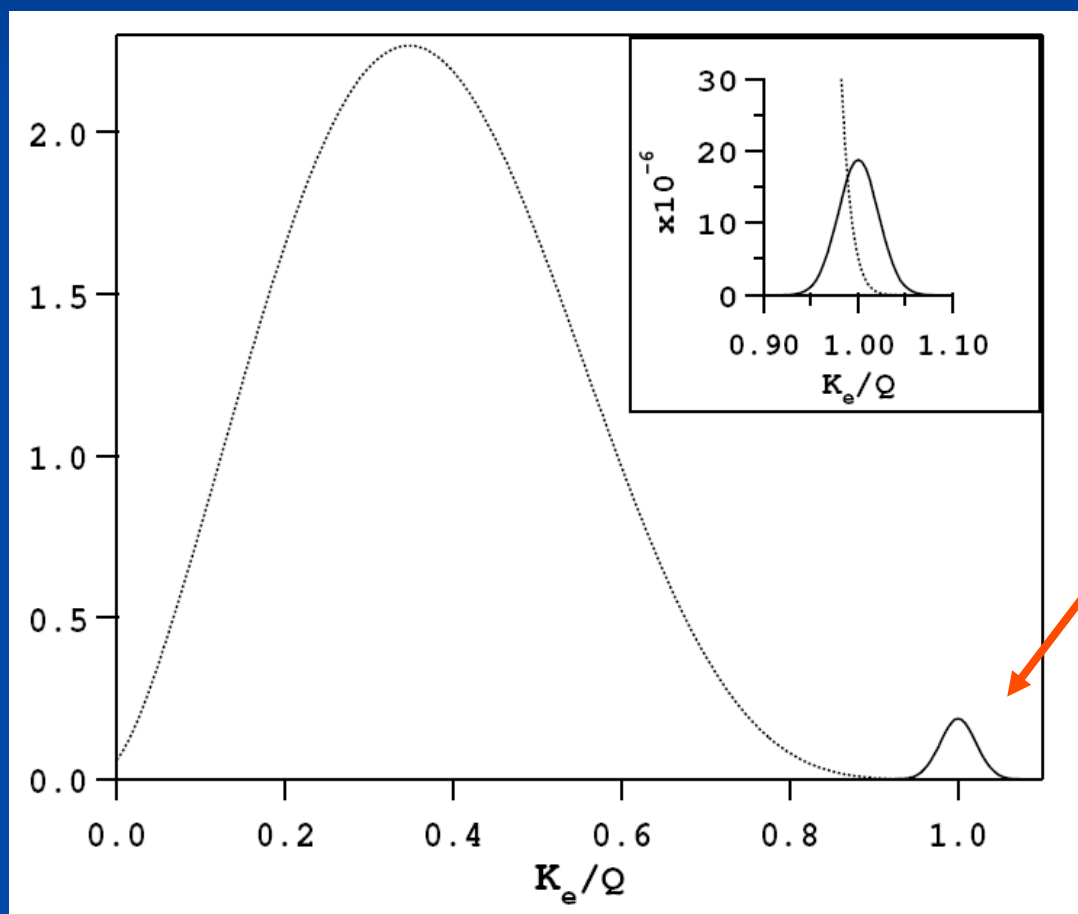
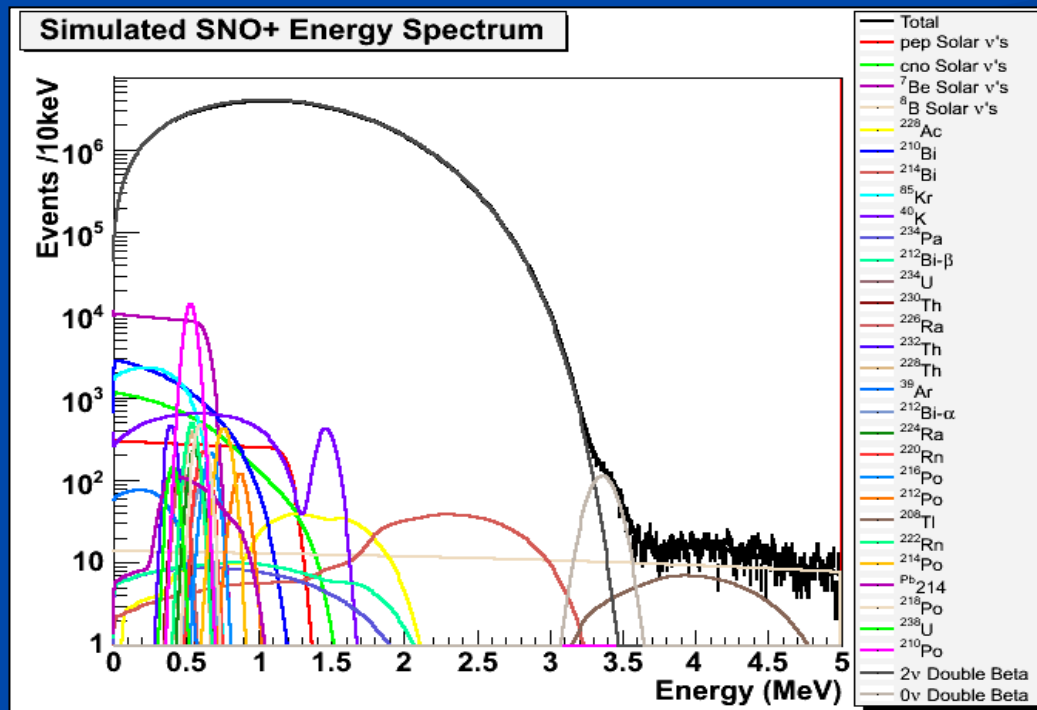


Image from Elliott and Vogel, hep-ph/0202254

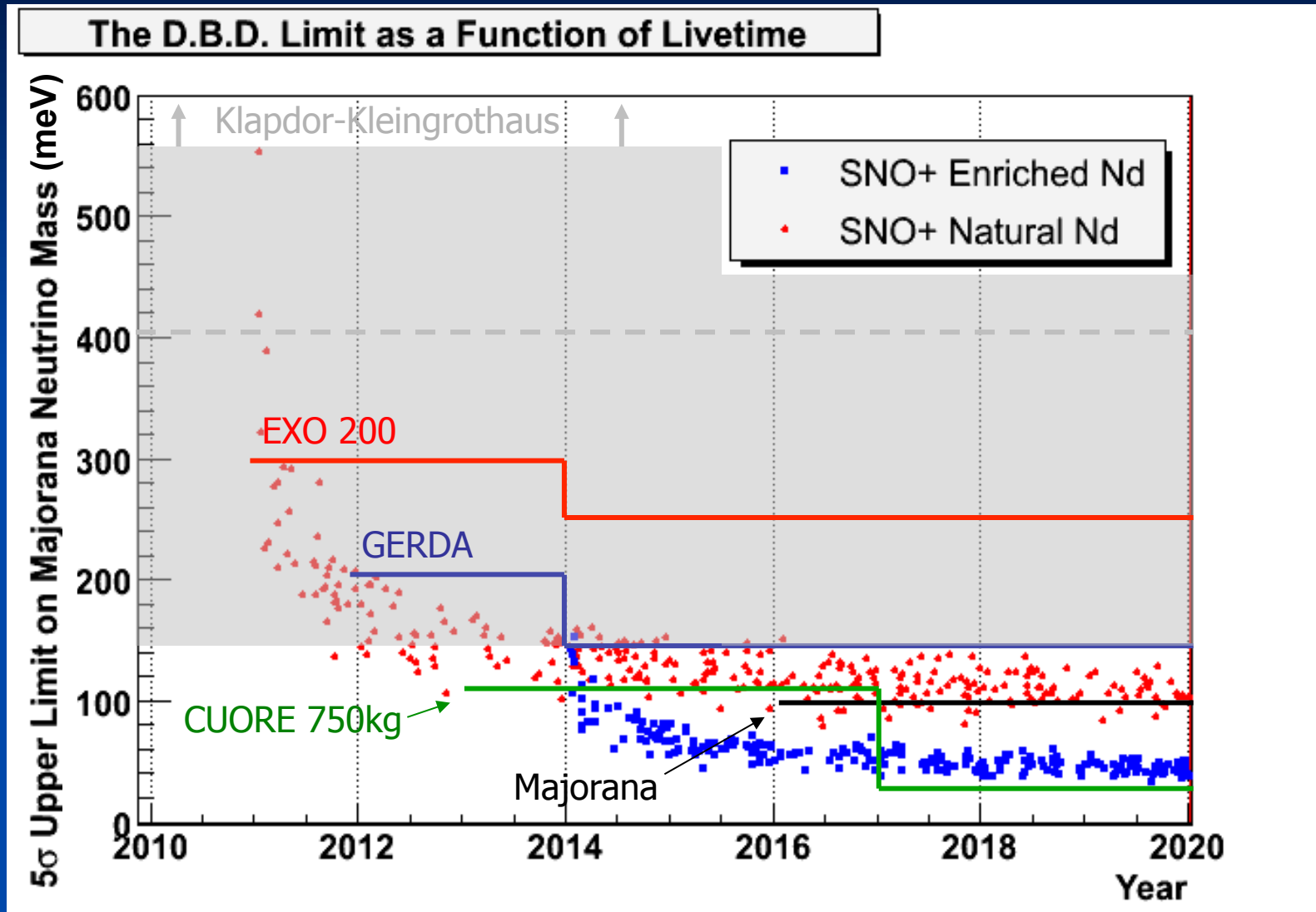
The size of the D.B.D. peak increases with the square of the neutrino mass!

Double Beta Decay in SNO+

- Loading ^{150}Nd into the SNO+ scintillator gives a huge amount of isotope
- SNO+ can fit for the spectral shape of the neutrinoless d.b.d. peak, rather than counting events in a bin
 - Much less sensitive to energy resolution, background
- SNO+ can stage a competitive next generation double beta decay experiment



SNO+ D.B.D. Sensitivity



SNO+ Estimate:

- Natural Nd in 2011
- Enriched Nd in 2014
- 50% fiducial volume
- 75% livetime

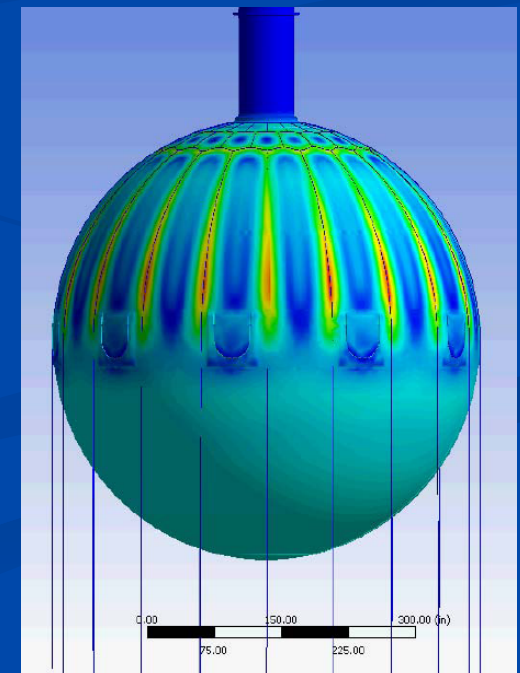
Physics Summary

- Particle Physics
- Solar Physics
- Geo-Physics
- Supernova Physics

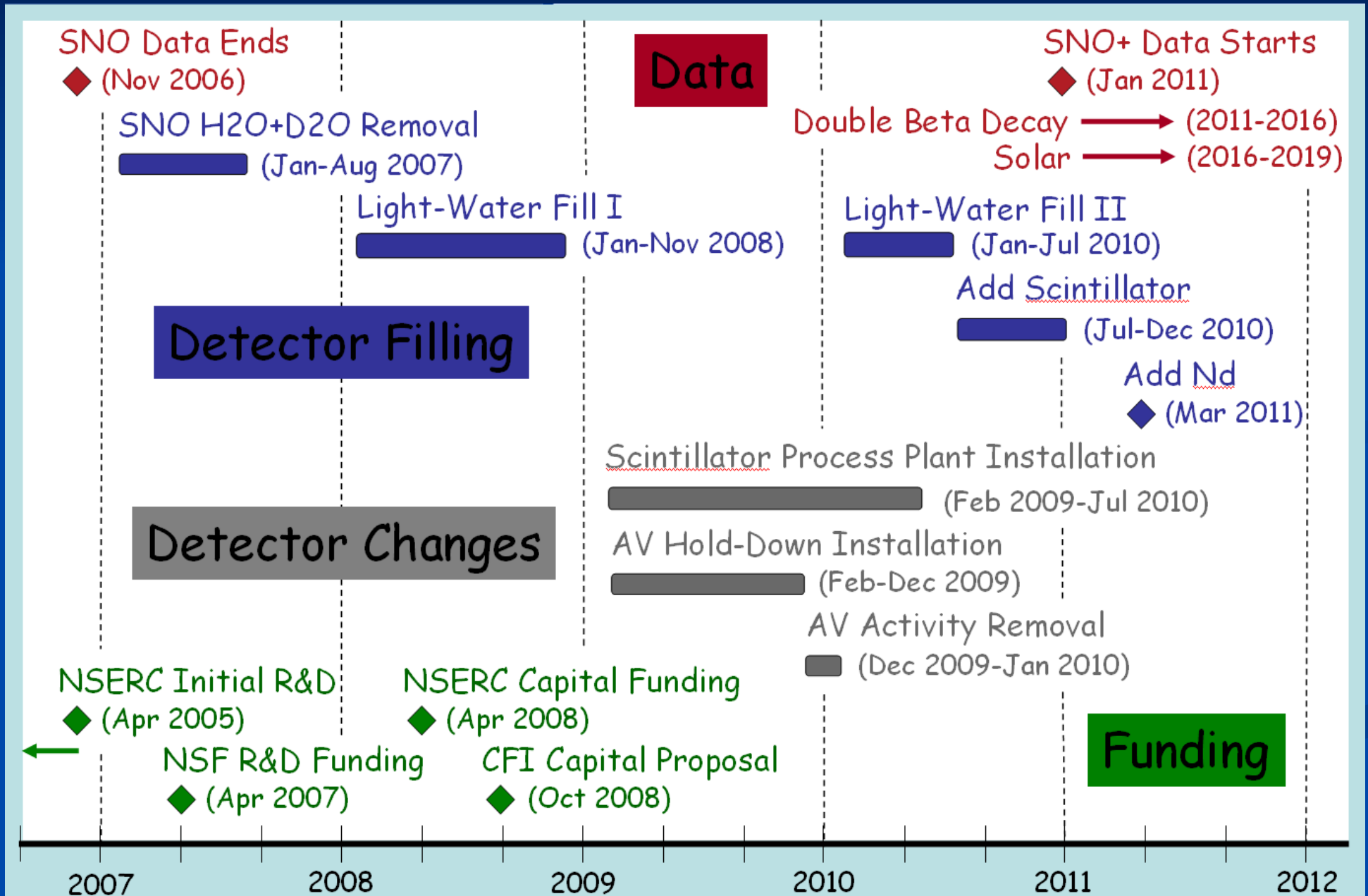
SNO+ will contribute to many different disciplines in physics!

SNO+ Status

- Cavity and acrylic vessel are currently filled with light water
 - Testing fiber optic calibration system
 - Performing calibrations to monitor the state of the PMTs/electronics
 - Working on DAQ upgrades/remote operation
- Scintillator purification plant quote expected in a few months
- Acrylic vessel holddown design is being finalized
- Techniques are being developed to clean radon daughters from the inside surface of the AV



SNO+ Schedule and Milestones



SNO+ Collaboration

University of Alberta:

R. Hakobyan, A. Hallin, M. Hedayatipoor, C.
Krauss, C. Ng

Brookhaven National Laboratory:

R. Hahn, Y. Williamson, M. Yeh

Idaho National Laboratory:

J. Baker

Idaho State University:

J. Heise, K. Keeter, J. Popp, E. Tatar, C. Taylor

Laurentian University:

E.D. Hallman, S. Korte, A. Labelle, C. Virtue

LIP Lisbon:

S. Andringa, N. Barros, J. Maneira

Oxford University:

S. Biller, N. Jelley, P. Jones, J. Wilson-Hawke

University of Pennsylvania:

E. Beier, H. Deng, W.J. Heintzelman, J.
Secrest, T. Sokhair

Queen's University:

M. Boulay, M. Chen, X. Dai, E. Guillian, P.J.
Harvey, C. Kraus, X. Liu, A. McDonald,
H.O'Keeffe, P. Skensved, A. Wright

SNOLAB:

B. Cleveland, F. Duncan, R. Ford, C.J. Jillings,
I. Lawson

University of Sussex:

E. Falk-Harris, S. Peeters

Technical University of Dresden:

K. Zuber

University of Texas at Austin:

J. Klein

University of Washington:

M. Howe, K. Schnorr, N. Tolich, J. Wilkerson